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B. T. GALLOWAY, Chief of Bureau.

THE SHRINKAGE OF CORN IN STORAGE.

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THE SHRINKAGE OF CORN IN STORAGE.

INTRODUCTION.

As the question of the natural shrinkage of shelled corn while in storage and in transit is of considerable importance to those engaged in the handling of grain, a series of special investigations was begun at Baltimore, Md., in order to determine the amount of shrinkage or loss in weight occurring in shelled corn containing various percentages of moisture while in storage in elevators or during transit in cars.

The experiment described in this circular, the first of the series on shrinkage, was made with 500 bushels of shelled corn stored on a 30,000-pound scale and was carried on in cooperation with the Baltimore & Ohio Railroad Co. and the Baltimore Chamber of Commerce.

EXPERIMENT WITH CORN STORED ON A SCALE IN A GRAIN ELEVATOR.

On January 5, 1910, 500 bushels (28,000 pounds) of shelled corn having an average moisture content of 18.8 per cent were placed in the wooden hopper of a 30,000-pound scale in Elevator B of the Baltimore & Ohio Railroad Co. at Locust Point (Baltimore), Md. The scale was tested prior to the beginning of the experiment, and after being filled with grain the hopper of the scale was covered with cloth to prevent an excessive quantity of dust from settling on the corn, and at the same time to permit a fairly free circulation of air over the top of the grain.

The corn used in this test was taken from the regular car receipts and was left in the hopper of the scale without handling from January 5 until May 14, a period of 129 days. It was then run out of the hopper and elevated three times to the same scale, the weight of the grain being taken after each elevation. After the third elevation the corn was held on the scale for an additional period of 18 days, or until June 1, at which time the experiment was terminated, making a total storage period of 147 days.

Figure 1 is a sectional view through the middle of the hopper of the scale, showing the position of the four electrical-resistance thermometers which were placed in the corn at the top of the first, second, fourth, and fifth 100-bushel drafts, respectively, in order that the temperature of the corn could be ascertained at any time throughout the course of the experiment.

The average condition and quality of the 500 bushels of corn at the beginning of the experiment, as represented by the results of the analyses of samples taken from the various drafts at the time the hopper of the scale was being filled, are shown in Table I.

TABLE I.—*Factors indicating the condition and quality of the corn tested when placed on the scale on January 5, 1910.*

Location of sample on scale.	Moisture content.	Weight per bushel.	Sound corn.	Germination of whole kernels.
	Per cent.	*Pounds.*	*Per cent.*	*Per cent.*
First 100 bushels	18.7	54.8	98.2	87.5
Second 100 bushels	18.8	54.8	97.6	91.0
Third 100 bushels	19.0	54.5	96.2	87.5
Fourth 100 bushels	18.5	54.8	97.3	91.5
Fifth 100 bushels	19.0	54.5	96.1	90.5
Average	18.8	54.7	97.1	89.6

As will be seen in Table I, the moisture content of the corn when placed on the scale on January 5 varied from 18.5 per cent in the fourth draft to 19 per cent in the third and fifth drafts, with an average of 18.8 per cent for the entire 500 bushels. The weight per bushel was 54.5 pounds in the third and fifth drafts and 54.8 pounds in the first, second, and fourth drafts, the average for the entire lot being 54.7 pounds. The average percentage of sound corn was 97.1 per cent and the average percentage of germination was 89.6 per cent.

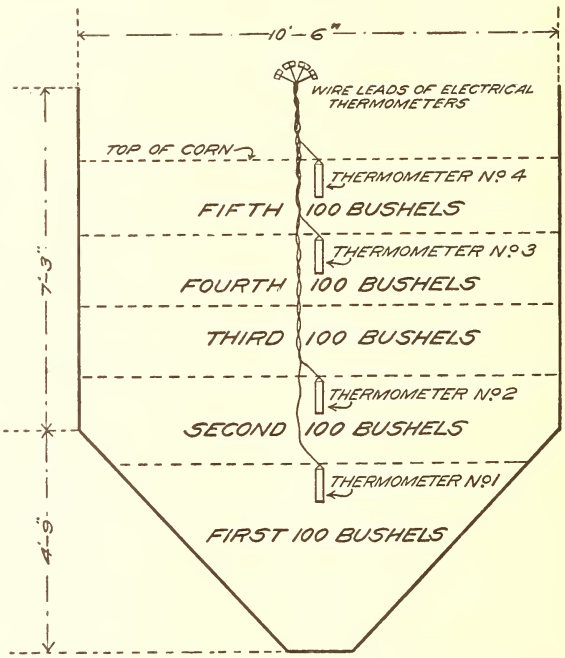

FIG. 1.—Diagram giving a sectional view through the center of the wooden hopper of the scale, showing the position of the four electrical-resistance thermometers in the stored corn.

SHRINKAGE IN THE WEIGHT OF THE STORED CORN.

Weighings and temperature records were made of the corn at frequent intervals throughout the experiment, during which time consideration was also given to the temperature and relative humidity

of the atmosphere and to general weather conditions. The results of these records and observations are shown diagrammatically in figures 2 and 3. Figure 2 shows the shrinkage in the weight of the corn, the average temperature of the corn, the average of the daily mean air temperatures for the periods between weighings, the mean daily relative humidity of the atmosphere, and the weather record from January 5 to April 21, after which time the rate of deterioration in the corn was such that the relative humidity of the atmosphere and the general weather conditions exerted no apparent influence on the amount of shrinkage. Figure 3 shows only the shrinkage in the weight of the corn, the average temperature of the corn as indicated by the four electrical-resistance thermometers at the time the weighings were made, and the average of the daily mean air temperatures for the periods between the dates of the weighings from the beginning of the experiment, January 5, until June 1, at which time the test was terminated.

Immediately after the corn was placed in the hopper of the scale the average temperature of the corn, as indicated by the four electrical-resistance thermometers, the positions of which are shown in figure 1, was 20° F., the same as the temperature of the air. From figures 2 and 3 it will be seen that the shrinkage in weight from January 5 to February 24, 50 days, was 30 pounds, or slightly more than one-tenth of 1 per cent. The temperature of the corn at this time, as shown by the average of the readings of the four thermometers, was 32.5° F., an increase of 12.5 degrees over the average temperature of the corn when it was placed on the scale. The average of the daily mean air temperatures for one week prior to February 24 was 33° F., or 13 degrees above the temperature of the air at the beginning of the experiment. From February 24 to April 8, 43 days, the loss in weight amounted to an additional 30 pounds, making a shrinkage of 60 pounds, or approximately two-tenths of 1 per cent, for the first 93 days of the test. The increase in the average temperature of the corn during this period of 93 days from the beginning of the test was 26.3 degrees.

On April 21 the average temperature of the corn was 69.5° F., an increase of 23.2 degrees for the 13 days from April 8 to April 21, during which period there was a further loss in weight of 47.5 pounds, or nearly two-tenths of 1 per cent, and for the whole period, January 5 to April 21, 106 days, the shrinkage amounted to 107.5 pounds, or approximately four-tenths of 1 per cent. The highest temperature at any point in the corn at this time was 87° F., as was shown by thermometers Nos. 3 and 4 in the upper part of the grain, while thermometers Nos. 1 and 2 showed a temperature of only 51° and 53° F., respectively. At this time the corn in the scale showed the first distinct signs of going out of condition, and this deterioration

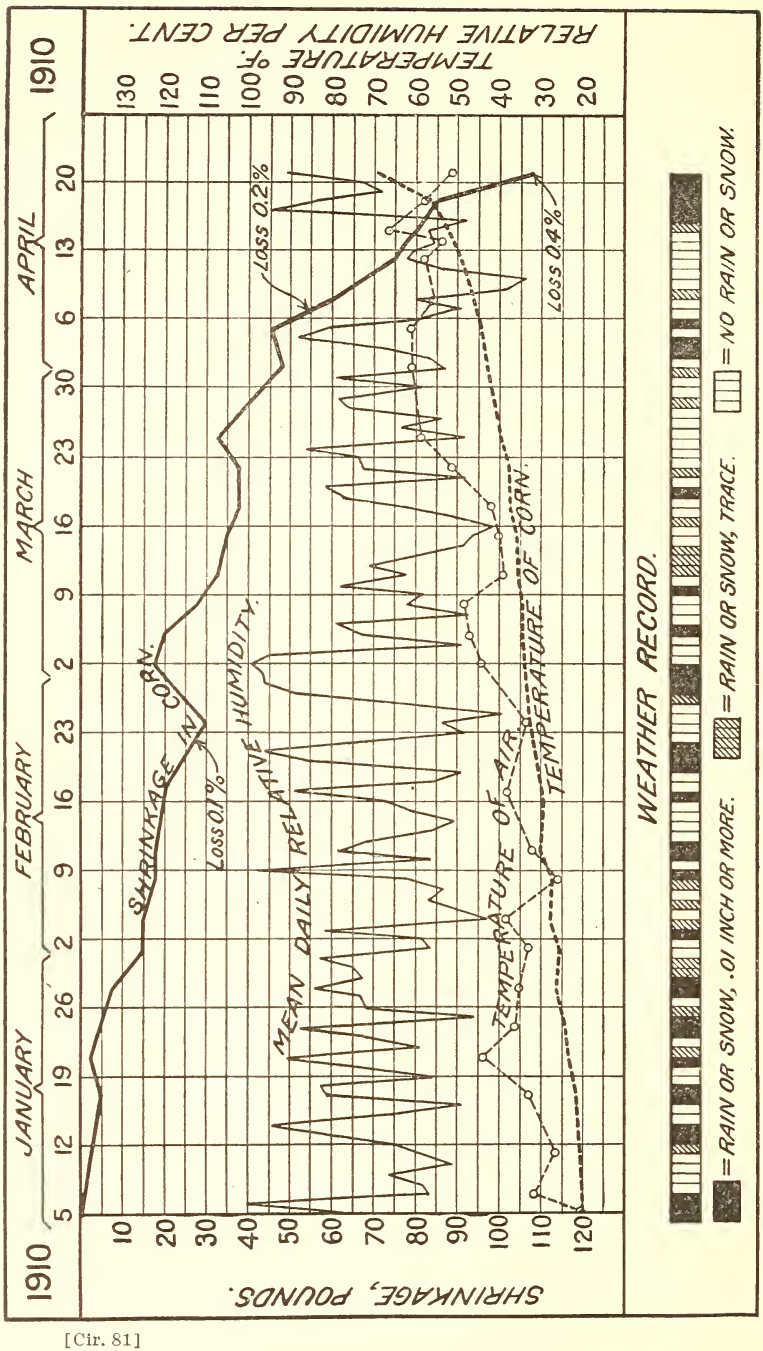
1910
JANUARY
FEBRUARY
MARCH
APRIL
1910
5 12 19 26 2 9 16 23 2 9 16 23 30 6 13 20
SHRINKAGE, POUNDS.
10 20 30 40 50 60 70 80 90 100 110 120
TEMPERATURE °F.
RELATIVE HUMIDITY PER CENT.
130 120 110 100 90 80 70 60 50 40 30 20
SHRINKAGE IN CORN.
Loss 0.1%
Loss 0.2%
Loss 0.4%
MEAN DAILY RELATIVE HUMIDITY.
TEMPERATURE OF AIR.
TEMPERATURE OF CORN.
WEATHER RECORD.
= RAIN OR SNOW, .01 INCH OR MORE.
= RAIN OR SNOW, TRACE.
= NO RAIN OR SNOW.

FIG. 2.—Diagram showing the shrinkage in weight of the corn, the average temperature of the corn, the air temperature (averages of the daily means for the periods between weighings as indicated by the small circles), the mean daily relative humidity, and the weather record from January 5 to April 21, while the corn remained in good condition.

was accompanied by a rapid rise in the temperature of the corn and a very marked increase in the rate of shrinkage, as illustrated in figure 3.

During the eight days from April 21 until April 29 the loss in weight was five-tenths of 1 per cent, or one-tenth of 1 per cent more than the loss from January 5 to April 21, the period of 106 days in which the corn remained in good condition. The increase in the average temperature of the corn from April 21 to April 29 was from 69.5° F. to 108° F., or 38.5° degrees. The maximum temperature recorded on April 29 was 130° F. at the top of the fourth 100 bushels, as compared with a maximum of 87° F. on April 21.

During the 15 days immediately following, April 29 to May 14, the shrinkage amounted to slightly more than 2 per cent. The average temperature of the corn on May 14 was 111.3° F. The maximum temperature of the corn on May 14 was 119° F. around thermometer No. 3, as compared with a maximum of 133° F. two days previous. The decrease in the temperature of the corn at this time was due to a reduction in the biochemical changes and to the decreased activities of the organisms responsible for the deterioration, influenced in a measure, perhaps, by the sudden drop in the air temperature.

The total shrinkage in the corn from January 5 to May 14 was 815 pounds, or approximately 3 per cent. The maximum average temperature of the corn for any given date, as shown by the four electrical-resistance thermometers, was 127° F. on May 5. The highest temperature recorded was 138° F. on May 2 around thermometer No. 3 at the top of the fourth 100 bushels, as compared with an average temperature of 20° F. at the beginning of the test.

On May 14 the corn, after it had remained in the hopper of the scale for 129 days without handling, was "run out" and elevated three times to the same scale. On the first elevation the loss was 205 pounds, or approximately eight-tenths of 1 per cent; on the second elevation the loss was 170 pounds, or approximately six-tenths of 1 per cent; and on the third elevation the loss was 73 pounds, or approximately three-tenths of 1 per cent. The total loss during the three elevations was therefore 448 pounds, or 1.6 per cent, on the basis of the original 28,000 pounds, or 1.65 per cent on the basis of the actual weight of corn in the hopper of the scale just previous to "handling."

The average moisture content of the samples drawn from the corn immediately prior to the third elevation was 16.5 per cent, as compared with an average moisture content of 18.8 per cent when the corn was first placed in the hopper of the scale, while the percentage of sound corn had decreased from 97.1 per cent to 7.6 per cent within the same period of storage.

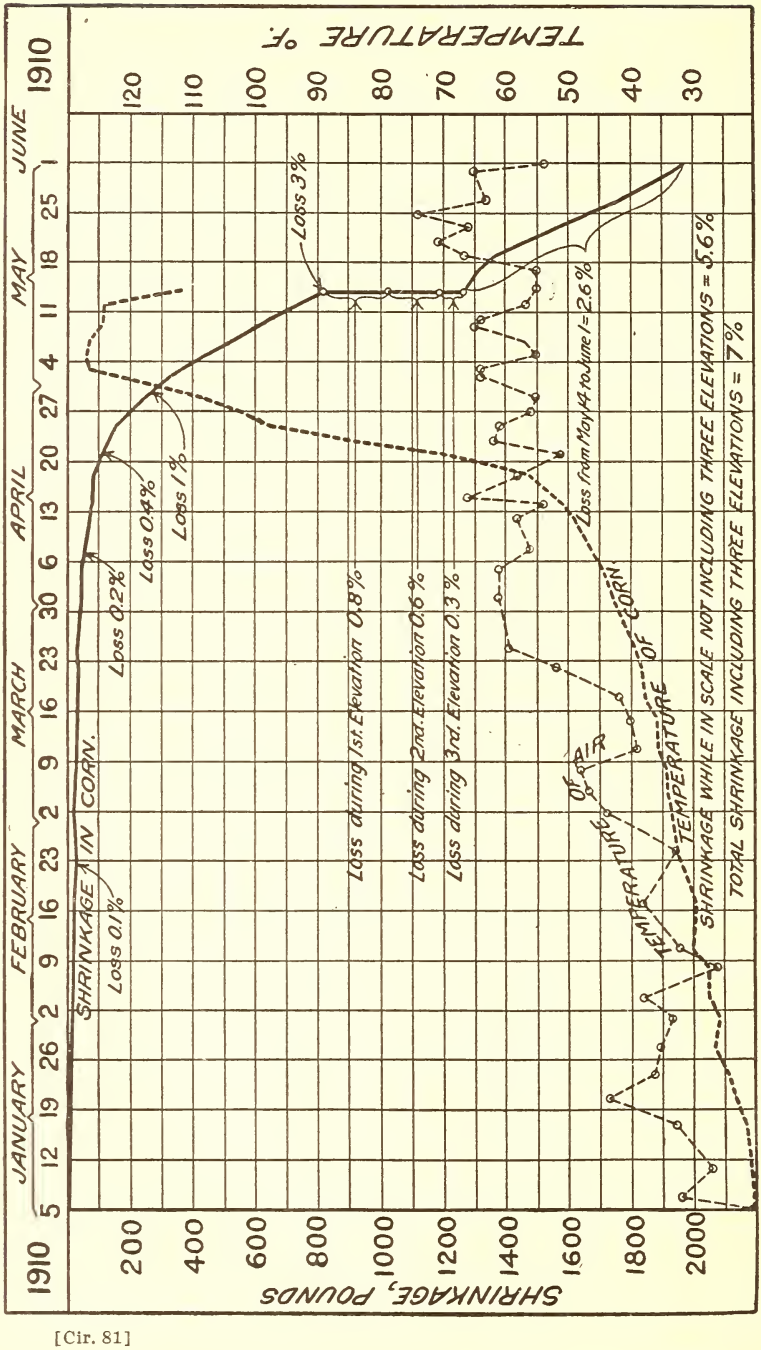

FIG. 3.—Diagram showing the shrinkage in weight of the corn while on the scale and during elevation, the average temperature of the corn, and the temperature of the air (averages of the daily means for the periods between the weighings as indicated by the small circles).

When the corn was returned to the scale on May 14, after the third elevation, the temperature of the corn was practically the same as the temperature of the air at the time the corn was handled, which was slightly less than 55° F. The corn was then held on the scale until June 1, when the corn was again hot. At this time the experiment terminated. During this final period of 18 days the additional loss in weight amounted to 707 pounds, or 2.6 per cent.

On the basis of the original weight, after deducting the weight of the samples drawn for analyses, the total shrinkage during the whole storage period of 147 days, not including the loss during the three elevations, was 1,522 pounds, or approximately 5.6 per cent. The total shrinkage, including the shrinkage of 448 pounds during the three elevations, was 1,970 pounds, or slightly more than 7 per cent. On June 1, at the termination of the experiment, the average moisture content of the corn was 14.7 per cent, or 4.1 per cent less than the same corn contained at the beginning of the test on January 5. During the same period there was likewise a marked change in the quality of the corn, showing that there had been a partial decomposition of the reserve food products during the course of the test resulting in a shrinkage in weight far in excess of the reduction in the percentage of moisture. The weight per bushel of the corn had decreased from 54.7 pounds to 50 pounds; the sound corn from 97.1 to 1.1 per cent, and the kernels which were capable of germination from 89.6 to 1 per cent.

EFFECT OF ATMOSPHERIC CONDITIONS ON THE SHRINKAGE OF CORN.

It was found that the shrinkage was not constant, but that during certain periods there was a retardation in the rate of shrinkage or even a temporary increase in weight due to the absorption of moisture from the atmosphere. In this connection it must be borne in mind that the hopper of the scale, being of wooden construction, undoubtedly absorbed moisture from the atmosphere on damp and rainy days the same as the corn.

Figure 2 shows that whenever there was an increase in weight or a retardation in the shrinkage the relative humidity of the atmosphere was very high between weighings, and in most cases a heavy rainfall occurred just before such weighings were made. The reverse, however, is not true in all cases; that is, all periods of high relative humidity do not show in the diagram a corresponding increase in weight, because the weighings were made only at irregular intervals while the relative humidity records are daily.

On January 21 there was an increase over the previous weighing, January 17, of 2.5 pounds. The relative humidity on January 17 was 81.5 per cent, and on January 21 it was 90.5 per

cent. The average relative humidity during this period was 74.5 per cent. On March 2 there was an increase in weight of 12.5 pounds over the previous weighing, February 24. The average relative humidity during this period was 81.4 per cent. On February 28 and March 1 and 2 the relative humidity was 96, 97, and 99 per cent, respectively. On February 28 the precipitation amounted to 0.71 of 1 inch, followed by 0.12 of 1 inch on March 1 and 0.03 of 1 inch on March 2. From this time on until March 22 the amount of precipitation was very small and the average relative humidity was low. During this period the shrinkage was quite rapid. On March 24 the relative humidity was 86 per cent, and when the corn was weighed on March 25 there was an increase of 5 pounds over the previous weighing on March 22. The weighing made on April 5 showed a gain in weight of 2.5 pounds as compared with the weight on April 1. Here again the relative humidity was high, being 87.5 per cent on April 4 and 81 per cent on April 5. There was also 0.24 of 1 inch of rainfall during this period. After April 5 the relative humidity was comparatively low until April 17, when it reached 95 per cent, and on April 21 the relative humidity was 90.5 per cent. At this time the corn showed signs of heating and therefore the influence of the relative humidity and general atmospheric conditions was lost in the increased amount of shrinkage which accompanied the comparatively rapid deterioration of the corn.

SUMMARY.

(1) The shrinkage test described in this circular was made with 500 bushels of shelled corn stored in the hopper of a scale in a grain elevator, and extended over a period of 147 days, January 5 to June 1, 1910, during which time the corn was not "handled" except on May 14.

(2) At the beginning of the test the average moisture content of the corn was 18.8 per cent. The average temperature of the corn and the temperature of the air was 20° F.

(3) The shrinkage in weight from January 5 to April 21, while the corn remained in good condition, was approximately four-tenths of 1 per cent.

(4) The shrinkage in weight from April 21 to May 14 was approximately 2.6 per cent, during which time the corn went "out of condition," becoming sour and hot, with a maximum temperature of 138° F. on May 2.

(5) The shrinkage during the three elevations on May 14 was 448 pounds, or 1.65 per cent, on the basis of the actual weight of corn in the hopper of the scale just previous to "handling."

(6) The shrinkage during storage from May 14 to June 1, after the corn was cooled to 55° F. by handling, was 2.6 per cent.

(7) The total shrinkage during the test was 1,970 pounds, or slightly more than 7 per cent, while the natural shrinkage exclusive of the loss during the three elevations was 1,522 pounds, or approximately 5.6 per cent, calculated on the actual weight after making deductions for samples drawn for analyses.

(8) The rate of shrinkage while the corn remained in good condition was largely influenced by the weather conditions and by the relative humidity and temperature of the atmosphere.

Approved:

JAMES WILSON,
Secretary of Agriculture.

WASHINGTON, D. C., *April 24, 1911.*

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